

Of the substances used, the above showed the effect best, but with wood, paraffin, and water, although small, it could always be detected. We conclude from the above results that the Röntgen rays are of different kinds, and that the substances given in the table differ very much from tinfoil in their selective absorption. After the rays have been screened by passing through some tinfoil layers additional layers are much less absorbent, while the absorption produced by other substances is not so much diminished.

Of the substances tried, those which are fluorescent gave the most marked difference as compared with tinfoil.

The above results were all obtained with one vacuum tube, which was working extremely well. It produced a very rapid leak from the charged disk, and the pressure of its residual air was very small. In fact, after working for a time it became too strong for the coil that was being used to work it. Another vacuum tube, in which the pressure of the residual air was greater and which was not so efficient in producing leakages, was then used, and several of the substances used before were again tested, but in no case was any evidence of selective absorption obtained. As far as the test was efficient, the radiation from this bulb was homogeneous.

A third tube was then used, more efficient than the last in producing leakage, but not so good as the first used. With this tube experiments made in the same way as before gave evidence of selective absorption, but not so marked as with the first tube.

It seems therefore that as a tube becomes more efficient the character of the rays given off becomes less homogeneous.

“On the Structure of Metals, its Origin and Changes.” By F. OSMOND and W. C. ROBERTS-AUSTEN, F.R.S., Professor of Metallurgy, Royal College of Science. Received June 10, —Read June 18, 1896.

(Abstract.)

The authors begin their paper by stating that it has been shown by Herbert Tomlinson that the atomic volume of metals is intimately connected with their thermal capacity* and with Young's modulus.† He considers, in view of the work of Wertheim,‡ of Maxwell,§ and of Heen,|| and as the result of his own experiments, that the value of

* ‘Roy. Soc. Proc.’ vol. 38 (1884–85), p. 488.

† ‘Phil. Trans.’ Part I, 1883, p. 32.

‡ ‘Ann. de Chim. et de Phys.’ vol. 12, 1844.

§ ‘Phil. Trans.’ vol. 156, 1866, p. 249.

|| ‘Bull. de l'Acad. Roy. de Belgique,’ vol. 4 (1882).

the product of the elasticity E , when multiplied by a fractional power of the atomic volume $\frac{A}{D}$, is a constant for all metals,

$$E\left(\frac{A}{D}\right)^{\frac{2}{3}} = 181 \times 10^4.$$

The divergences shown by several metals from this mean value arise from the fact that the presence of small amounts of impurity makes a great difference in their elasticity.

Sutherland* finds a close relation between the atomic volume and the rigidity of metals, and considers that this rigidity is "in its essence a kinetic phenomenon, almost as simple in character as the elasticity of perfect gases."

Professor Fessenden,† moreover, has urged that the cohesion of metals is proportional to some power of the atomic volume, and he considers that the rigidity varies as the fifth power of the distance of the centre of the atoms, or as (atomic volume) $^{\frac{5}{3}}$. It will be evident, therefore, that the atomic volume of a metal is very important.

One of the authors purified gold with great care, and alloyed seventeen separate portions of it with foreign elements in quantities which were in each case close to 0.2 per cent., and from each sample of this alloyed gold, bars were cast, 88 mm. long by 7.5 mm. wide by 5.2 mm. thick. The tensile strength, elongation, and reduction of sectional area (striction) were determined, and the results were published in the 'Phil. Trans.' in 1888. These results indicated in a general way, that the tenacity and ductility of gold is increased by the presence of 0.2 per cent. of an added element of smaller atomic volume than that of gold itself, while, on the other hand, these properties are diminished when the atomic volume of the added element is greater than that of gold.

There are, as might be expected, exceptions and irregularities, but it is strange that they are not more numerous and more marked. Even the purest metals are not, from a mechanical point of view, homogeneous. Under the influence of internal forces which tend to make them crystalline, and of external stresses which are set up by contraction during cooling, the invisible molecules become arranged in visible and more or less highly organised groups. These groups are separated from each other either by planes of cleavage or by joints which are often surfaces of least cohesion, and, therefore, of weakness. This is especially the case when these joints have been accentuated by the evolution of dissolved gas at the moment of the solidification of the metal. In alloys, chemical homogeneity may, in turn, disappear,

* 'Phil. Mag.,' vol. 32, 1891, p. 41.

† 'Chem. News,' vol. 66, 1892, p. 206.

and free metals, chemical compounds, or various alloys may fall out of solution from the liquid mass, and, finally, the *eutectic* alloy solidifies, but its presence, as a residual fluid facilitates the arrangement of the parts which have previously solidified.

One of the authors in collaboration with M. Werth* was probably the first to direct attention to the influence which these fusible residues, to which the name of "cements" was given, exert on the working of steel and on the mechanical properties of the finished products of steel manufacture. Since then M. André le Chatelier† has repeatedly insisted on this point, correctly enough as a principle, though perhaps with a tendency to generalise too much from ideas which are, in themselves, accurate.

It is possible to distinguish in metals and alloys both the *visible* structure and the *molecular* structure, and between them, such methods of investigation as it is possible to adopt, enable a well defined line of demarcation to be traced. Attention must, therefore, be directed to ascertaining to what extent the mechanical properties of a given sample of metal are due to each of these kinds of structure, and how far to their mutual relations. This being the case, the authors considered that it would be interesting to submit the gold, containing 0·2 per cent. of various elements, to micrographical examination, and, fortunately, the identical specimens which were submitted to the Royal Society, eight years ago, had been preserved intact, and were available for examination.

Descriptions are then given in detail of the methods adopted in preparing, polishing and etching the micro-sections of gold alloyed with various impurities, photographs of which sections illustrate the paper. It is difficult to give a brief abstract of the authors' conclusions, but they may be stated as follows. They consider it to be certain that there is no relation between either the structure, the appearance of the fractures, the melting points of the alloyed elements and the mechanical properties of the masses of alloyed gold. They observe that every iron metallurgist who examined the photograph of the micro-section of gold with potassium would form a highly favourable opinion as to the mechanical properties of the mass it represents, while it is really, from a mechanical point of view, the worst of the series. On the other hand he would think that the micro-section of the gold alloyed with zirconium, indicated a structure of deplorable weakness, while as a matter of fact it might equally well represent alloys which vary in tenacity from less than half a ton per square inch to $7\frac{1}{2}$ tons, and are either incapable of being extended, or will elongate 30 per cent.

The authors then proceed to examine the structure of the various sec-

* Osmond and Werth, 'Ann. des Mines,' vol. 8, 1885, p. 5.

† 'Inst. Mech. Engineers Proc.,' April, 1893, p. 191.

tions in detail, and they conclude the first part of the paper by stating that they do not contest in any way, as their previous publications abundantly prove, the importance of the part which may be played in the mechanical properties of the alloys by the residues which remain liquid after the main mass of the alloy has solidified, the alloys being tested either at the ordinary temperature or when heated. But, in order that it may be possible for such cements to intervene and affect the mechanical properties of alloys, the cements must at least have a real existence. Nothing indicates that they do exist in ten out of twelve of the alloys examined. The authors do not express themselves too positively on this point, for some new method of etching may reveal new facts. The impurities which are sought for may happen to concentrate themselves beyond the particular region which has been sectioned. These are, however, gratuitous suppositions. Polishing only indicates the presence of cement in two cases. The little secondary crystals which are described in the paper might readily be mistaken for cements, of definite or indefinite composition, if they were found only in certain specimens, and then in such proportions as could be accepted. But they occur everywhere, and in all cases with identical appearances, forms, and dimensions; and, moreover, are seen to be collected into crystallites which pervade the whole mass. These are, therefore, usually and indubitably due to the crystallization of gold itself, although the alloying substances sometimes (indium and probably potassium) join up the crystals in question. For the same reason the dark line of the joints, traced as furrows by the etching, are very rarely the empty tracks of cement which has been dissolved away by *aqua regia*; their formation, which it is easy to follow in all its phases, directly connects them with secondary crystallization. The authors are led to the belief that in the case of ten of their alloys of the gold with about 0.2 per cent. of various impurities, solidification of the whole mass has been directly accomplished at a single time, and that the foreign bodies have remained as *solidified* solutions, as they were *fluid* solutions when the alloys were liquid, the impurities being dissociated into their ions in both solid and liquid. Under these conditions it is difficult to invoke, as explaining the mechanical properties of the alloy, the intervention of hypothetical "cements" with relatively low fusing points.

In the second part of the paper attention is directed to the fact that gold alloyed with bismuth, thallium, antimony, and aluminium has its structure entirely changed by annealing it in sulphuric acid at about 250°. The large grains of the metal become divided into a multitude of little polyhedral grains. Nothing remains of the original structure, and the effect closely resembles that which is obtained by annealing steel castings at a bright red heat (800°). It is pointed out that whatever this observation may signify, the trans-

formation of the structure of a metal, at a temperature so far below its melting point, and, in the case of the gold-antimony and gold-aluminium series, far below the melting point of the *eutectic* alloys, in the presence of only two-tenths per cent. of a foreign body, is probably not an isolated fact, and appears to open a new field for research.

“On the Relations between the Viscosity (Internal Friction) of Liquids and their Chemical Nature. Part II.” By T. E. THORPE, LL.D., F.R.S., and J. W. RODGER, Assoc. R.C.S. Received May 27,—Read June 11, 1896.

(Abstract.)

In the Bakerian Lecture for 1894 the authors gave an account of their work on the viscosity of over seventy liquids, and they discussed the interdependence of viscosity and chemical composition. In order to render the investigation more complete, they have now made measurements of the viscosity of (1) a number of esters or ethereal salts, and (2) of ethers, simple and compound—groups of liquids, which with the exception of ethyl ether, have not hitherto been studied by them. The physicochemical relationships previously established made such determinations of special interest, for it was shown that one of the most striking of the various connexions traced between chemical constitution and viscosity was the influence exerted by oxygen according to the different modes in which it was assumed to be associated with other atoms in the molecule. The influence which could be ascribed to hydroxyl-oxygen differs to a most marked extent from that of carbonyl-oxygen, and it appeared that ether-oxygen, or oxygen linked to two carbon atoms, had also a value which differed considerably from oxygen in other conditions.

In the present paper the authors give the experimental values for the viscosity of the ten lowest fatty esters, carefully purified samples of which had been placed at their disposal by Professor Sydney Young. With the help of Mr. Barnett, B.Sc., Assoc. R.C.S., they have also investigated the viscosity of five fatty ethers. By the kindness of the Photometric Standards Committee they have also been enabled to make observations upon various samples of carefully prepared isopentane, and they have supplemented their former observations by a new series of experiments upon ethylbenzene, for a sample of which they are indebted to Dr. G. L. Moody, of the City and Guilds Central Institute.

The details of the observations are given in precisely the same manner as in the first paper, and formulæ of the Slotte type showing